TITLE OF THE INVENTION

Retroflector

CROSS-REFERENCES TO RELATED APPLICATIONS

This application claims the priority of German patent application Serial No 103 12 708.9 filed March 21st, 2003, the subject-matter of which is incorporated herein by reference.

FIELD OF THE INVENTION

The present invention generally concerns a retroreflector.

BACKGROUND OF THE INVENTION

Retroreflectors are used as reflective devices for marking articles and persons, the surface or clothing respectively of which greatly absorbs light and is therefore difficult to see in the dark, for example at night, even when strong lighting is involved. The retroreflectors are provided with reflective surfaces which are enclosed in a layer composite and are applied by means of adhesive for example to predetermined surfaces. In that way retroreflectors enhance the visibility of for example building barriers, optical markings, bicycles, motor vehicles and so forth.

Reference is made in this respect to US No 3 712 706 disclosing a retroreflector in which a relief structure is composed of reflective tetrahedron elements in the form of corner cubes. Production of the relief structure with the periodically arranged tetrahedron elements is effected by cutting three sets of parallel, V-shaped grooves into the surface of a metal master plate, by means of a diamond tool. The three sets with the parallel, V-shaped grooves intersect at predetermined angles in such a way that the surface of the metal master plate has the relief structure formed from the periodically arranged tetrahedron elements. Retroreflectors of that kind reflect incident light in a narrow spatial angle centered around the direction of the incident light. An increase in the angle of the reflected light is effected by diffraction of the light at the relief structure.

WO 00/43813 describes a retroreflector which in substance corresponds to US No 3 712 706 as just discussed above. Chips or small portions of such retroreflectors can be added as a pigment to a lacquer. An article which is coated with such a lacquer has a strongly reflective surface.

US No 1 671 086 provides the teaching of not excessively polishing the reflective surfaces of the retroreflector with the typical cube edge, so

that the reflected light can be scattered at the minor irregularities in the reflective surfaces of the retroreflector. The parallel light beam which is incident on the retroreflector is reflected and is returned in a cone with the incident light beam as the axis in a symmetrical condition in expanding relationship back to the light source.

Attention may be directed here to DE 44 29 683 C1 describing a triple reflector which is a body formed from structure elements, each of which is of a shape delimited by three reflective square faces. The three faces form a surface which corresponds to the cube surface which is visible in the direction of the cube diagonals. The three faces of each structure element can be slightly curved inwardly in the manner of a hollow mirror and may have a grooving so that the triple reflector reflects the incident parallel light beam back to the light source in divergent relationship.

Reference may also be made to US No 4 588 258 and US No 4 938 563 in which shaping the relief structure of a retroreflector in a flexible film material, by virtue of the small thickness of material involved, necessarily results in microscopically small lateral dimensions of the elements of the relief structure and consequently affords strong light diffraction effects. Minor asymmetries in the relief structure, which incline the axes of the tetrahedron elements through a few degrees of angle out of the normal direction, reduce the scatter of the reflected light. US No 4 938 563 more specifically refers to the possibility of influencing divergence or scatter of the reflected light by suitably arranging the tetrahedron elements, of differing asymmetrical nature, within the relief structure.

DE 696 19 691 T2 provides that the retroreflectors can be improved by a diffraction structure which is superimposed on the relief structure and which imparts to the reflected light a color which is dependent on the spatial frequency of the diffraction structure, without the use of colored pigments.

A summary of materials which are suitable for the production of layer composite material for retroreflectors is to be found in US No 4 856 857.

It will be appreciated that retroreflectors are readily commercially available. An aspect in common to such retroreflectors is that it is not

possible to derive any conclusions about the orientation of the retroreflector from the reflected light.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an inexpensive and efficient retroreflector involving novel structures which afford a predetermined modification in the light reflected by the retroreflector.

Another object of the present invention is to provide a retroreflector constituted by a layer composite of a specifically designed configuration to provide enhanced retroreflection.

Still another object of the present invention is to provide a retroreflector comprising a layer composite involving specifically selected materials and material parameters to afford a rationally implemented retroreflection effect.

In accordance with the principles of the present invention the foregoing and other objects are attained by a retroreflector comprising a plastic layer composite including at least one transparent structure layer, a protective layer, and a reflection layer enclosed at a common interface between the structure layer and the protective layer. The reflection layer has a relief structure which is formed by substantially identically shaped three-dimensional structure elements and the base surfaces of which are of lateral dimensions in the range of between 1 μm and 200 μm and whose side surfaces which are covered with the reflection layer include an angle of inclination of 45° relative to a free surface of the layer composite. The relief structure is superimposed in at least one surface portion or element with a microstructure distinguished by a preferred direction and for influencing the quality of the reflection action of the layer composite the microstructure in each surface portion or element has a single preferred direction.

Preferred and advantageous features of the present invention are set forth in subsequent claims.

Further objects, features and advantages of the invention will be apparent from the description hereinafter of preferred configurations of the invention.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 is a view in cross-section of a retroreflector according to the invention,

Figure 2 is a view on an enlarged scale of a portion of a relief structure from the Figure 1 retroreflector,

Figure 3 shows a matt structure,

Figure 4 shows a sign with retroreflectors,

Figure 5a shows a simple grating structure of the retroreflector,

Figure 5b shows a plan view of the Figure 5a grating structure,

Figure 6a shows a retroreflector with a pyramid structure,

Figure 6b shows a plan view of the Figure 6a pyramid structure,

Figure 7 shows a structure element with a tetrahedron structure,

Figure 8 shows a conical structure element, and

Figure 9 shows an example of use of a retroreflector according to the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Reference will first be made to Figure 1 in which reference 1 denotes a substrate, reference 2 denotes a layer composite, reference 3 a transparent structure layer, reference 4 a protective layer, reference 5 an adhesive layer and reference 6 a reflection layer. At least the structure layer 3, the reflection layer 6 and the protective layer 4, in the specified sequence, form the layer composite 3, while the substrate 1 is for example a removable backing or support strip for protecting the adhesive layer 5 which is possibly applied to the surface of the protective layer 4, that is remote from the structure layer 3, or alternatively it may be an article which is joined to the layer composite 2 by means of the adhesive layer 5 and to which the layer composite 2 is applied. In an embodiment of the layer composite 2 a tough, transparent base film 7 extends over the structure layer 3 and thus forms a further layer of the layer composite 2, as indicated in Figure 1. In another alternative configuration the base film 7 can be a laminating film which is secured by adhesive over the article in such a way that the layer composite 3 is accordingly enclosed between the article and the laminating foil.

The reflection layer 6 has a high level of reflectivity achieved by a metal layer applied for example by vapor deposition to the structured side of the structure layer 3. In that respect, aluminum, silver, chromium, gold, copper, tellurium and similar materials, as set forth for example in Table 5 of US No 4 856 857 to which reference is accordingly directed for incorporation of that disclosure herein, and possibly alloys of such metals may be mentioned as substances providing for good reflectivity with layer thicknesses in a range of between 10 nm and 150 nm. In a specific configuration of the layer composite 2 the reflection layer 6 may comprise one of the inorganic transparent materials set forth in Tables 1, 3 and 4 of above-mentioned US No 4 856 857, or one of the transparent chalcogenides known from above-mentioned WO 99/47983. Preferably materials such as TiO_2, ZnS, SiO_2 and so forth are used. Instead of a uniform layer, variants of the reflection layer 6 involve a thin film system. Examples in that respect are multi-layer systems comprising the above-mentioned inorganic dielectrics or combinations of metallic and dielectric layers. An embodiment of the layer composite 2 with a transparent reflection layer 6 advantageously only consists of transparent materials so that a sign or signal marking which is under the layer composite 2 is visible.

The interface between the structure layer 3 and the protective layer 4 has a relief structure 8 which is superimposed with a fine structure and which was shaped prior to application of the protective layer 4, in the structure layer 3. The relief structure 8 comprises structure portions or elements 9. The structure elements 9 have side faces 19 which face towards the structure layer 3 and which are covered by the reflection layer 6. The base surfaces of the structure elements 9 form a base plane 12 which is arranged in parallel relationship with the surface 11 of the protective layer 4. For reasons relating to clarity and ease of comprehension of the drawing, in Figure 1 one of the structure elements 9 is delimited by means of a broken line indicating the position of the base plane referenced 12.

The relief structure 8 is preferably of a structure depth as indicated at T of between 0.25 μm and 100 μm. The spatial frequency of the relief structure 8, in comparison with that of the fine structure superimposed thereon, is low, in which respect the structure elements 9, in the base plane 12, involve a lateral dimension as indicated by D in a range of between 0.5 μm and 200 μm. The preferred values of D are in a range of between D = 1 μm and D = 50 μm. The dimension D and the structure depth T are to be so selected that the side faces 10 which are covered by the reflection layer 6 are inclined with respect to the base plane 12 and include an angle of inclination ϑ of 45° with respect to the base plane 12. In other words, the dimension D is double the depth T, or $D = 2 \cdot T$. In a possible design configuration of the relief structure 8 the structure elements 9 are identical.

The above-mentioned base film 7 possibly protects the layer composite 2 from damage under the effect of mechanical forces acting thereon from the exterior. The base film 7 is arranged on the side of the structure layer 3, that is remote from the relief structure 8, and is fixedly joined to the structure layer 3. Base films of suitable materials such as polyethylene terephthalate, polycarbonate, polypropylene and so forth are highly transparent and resistant to abrasion and tensile forces. They already effectively protect the layer composite 2, when the thickness of the base film 7 is about 10 μm. At the left in Figure 1 the base film 7 is indicated by a dash-dotted line. In this configuration the exposed surface 11 is the side of the base film 7, that is remote from the main body part of the layer composite 2.

Suitable materials for the structure layer 3 and the protective layer 4 of the layer composite 2 are for example polymethylmethacrylate-based lacquers. UV-lacquers are advantageous for the structure layer 3, specifically for relief structures 8 involving large structure depths T. Radiation-hardening lacquers, for example UV-lacquers, harden under the effect of suitable radiation, for example upon being irradiated with ultraviolet light. In that case, during the hardening process, the relief structure 8 is formed in the UV-lacquer, while it is still of a kneadable or

pasty nature, of the structure layer 3. Reference may be made to above-mentioned US No 4 856 857 for the compositions of such lacquers, the disclosure thereof being hereby incorporated by reference. A cold adhesive or a hot melt adhesive may be suitably used for the adhesive layer 5. Reference may also be made in this respect to US No 4 856 857 for suitable adhesive materials.

Light as indicated at 13 and 13' which is incident through the surface 11 is reflected in the layer composite 2 at the reflection layer 6. Because of the angle of inclination ϑ of 45°, reflected light beams indicated at 14, 14' leave the layer composite 2 again only after double reflection in parallel relationship with the direction of the incident light 13, 13'. That applies in regard to a wide range of values of an angle of incidence α which is measured between the direction of the incident light 13, 13' and a normal 15 on to the free surface 11 of the layer composite 2. The values for the angle of incidence α are in a range of between 0° and about 75° and thus embrace practically the entire half-space over the layer composite 2. As the transparent plastic materials of the structure layer 3 usually involve a refractive index of about $n = 1.5$, the incident light beams 13' are deflected towards the normal 15 as refracted light beams 16, because of the refraction effect. Within the layer composite 2 the effective angle of incidence β between the refracted light beams 16 and the normal 15 is at most 45°. As the incident light 13, 13', irrespective of the angle of incidence α, is always reflected in the direction from which the incident light 13, 13' comes, corresponding layer composites 2 are known by the term retroreflector.

In an embodiment of the layer composite 2 the structure elements 9 involve small lateral dimensions in the range of some 10 micrometers or less. Therefore, unwanted diffraction effects occur at the structure elements 9, particularly when lighting using coherent light is involved. Advantageously, to suppress such unwanted diffraction effects, the structure elements 9 involving small lateral dimensions are no longer arranged exactly periodically on the base plane 12, but involve a quasi-random distribution on the base plane 12. Small reflective flat surface

portions of the base plane 12 can be present between the adjacent structure elements 9 and/or respectively adjacent structure elements 9 can move close together. The small proportion of volume of the structure shape, which is jointly occupied by the closely adjacently disposed structure elements 9, is of practically the same three-dimensional shape as the original structure elements 9. The relief structure 8 is therefore composed of substantially identical structure elements 9.

In another configuration, the local values in respect of the structure depth may be dispersed randomly around a mean value in respect of the structure depth T so that the unwanted diffraction effects at the structure elements 9 are also thereby suppressed. Those measures for reducing the unwanted diffraction effects can also be combined with each other.

Reference will now be made to Figure 2 showing an enlarged view which is not true to scale of the cross-section through the layer composite 2 indicated in Figure 1, with the relief structure 8 indicated in broken line. The side faces indicated at 10 in Figure 1, which are covered by the reflection layer indicated at 6 in Figure 1, form an interface between the structure layer 3 and the protective layer 4. The side faces 10 are not smooth but have a light-modifying fine structure to which reference has already been made hereinbefore. The fine structure which is for example additively, multiplicatively and so forth superimposed on the relief structure 8 is a microscopically fine microstructure 17 which influences the quality of the reflection action of the layer composite 2. The reflected light beams indicated at 14, 14' in Figure 1 are modified by the reflection action of the microstructure 17, for example in respect of color, polarisation, divergence and so forth.

Referring to Figure 2, the microstructure 17 illustrated therein is for example a linear diffraction grating with a sinusoidal profile. The diffraction grating can be characterised for example by a grating vector, a grating period, which can also be referred to as the line spacing, as indicated at d of less than 500 nm, and an optically effective fine structure depth t of between 20 nm and 1000 nm. The geometrical fine structure depth t_G which is to be shaped in the arrangement, in accordance with the refractive

index n of the structure layer 3 filling the microstructure 17, is less, that is to say $t_G = t/n$. The refractive index n of the structure layer 3 is typically in a range of between n = 1.5 and 1.6. The reference to the fine structure depth t hereinafter is always intended to denote the optically effective depth. The grating vector, the preferred direction k, of the diffraction grating is in the plane of the drawing in Figure 2.

Besides the sinusoidal profile involved here, other sine-like or rectangular profiles are also appropriate for the periodic, linear diffraction grating or cross grating which forms the microstructure 17.

Microstructures 17 whose diffraction gratings are of a value in respect of the grating period d of less than 350 nm are particularly advantageous for superimposition on the relief structure 8. Those diffraction gratings also diffract visible incident light 13 which impinges inclinedly on the side faces 10 only into the zero diffraction order, that is to say they reflect like a mirror, and therefore have no influence on the direction of the reflected light beams 14. In dependence on the grating period d the diffraction grating can suppress individual ranges in the visible spectrum of the incident light 13 so that the diffracted reflected light beams 14 are of a mixed color, that is to say the diffraction gratings act like flat colored mirrors.

Advantageously, the diffraction grating with the grating period d < 350 nm has a metallic layer 6 which is a good reflector and which comprises a suitable material such as silver, aluminum, gold or the like, or an alloy with one of those metals as its main component. The value of the fine structure depth t is desirably selected from a range of between 50 nm and 250 nm. In that range in respect of the fine structure depth t the diffraction grating acts as an effective polariser or as an analyser for polarisedly incident light 13. In that range in respect of the fine structure depth t, the TE polarised light is diffracted with a high level of efficiency practically independently of the fine structure depth t. In contrast thereto, the level of diffraction efficiency for the TM polarised light is heavily dependent on the fine structure t, while the diffraction efficiency for the TM polarised light rapidly falls to a first minimum, with an increasing fine

structure depth t. The maximum level of polarisation efficiency is therefore in the range of the fine structure depth t of the first minimum for the diffraction efficiency of TM polarised light. The direction of the unpolarisedly incident light 13 and the normal 15 establish a diffraction plane, being here the plane of the drawing in Figure 2. If the preferred direction k of the diffraction grating is in the diffraction plane, then the electrical field vector of the p-polarised light oscillates parallel to that plane as TE polarised light and is reflected by the diffraction grating with a high level of diffraction efficiency. The electrical field vector of the s-polarised light which oscillates perpendicularly to the diffraction plane is diffracted as TM polarised light with a low level of diffraction efficiency, that is to say it is practically absorbed. The diffracted reflected light beams 14 are therefore linearly polarised, in other words, the diffraction grating of the microstructure 17 acts as a polariser or, for the polarisedly incident light 13, as an analyser.

In a possible embodiment, the diffraction grating involves a grating period d = 300 nm, a sinusoidal profile and a reflection layer 6 which comprises aluminum. The maximum level of polarisation efficiency or the minimum degree of diffraction efficiency for the TM polarised light is in the preferred range of the fine structure depth of between t = 100 nm and t = 150 nm for light beams indicated at 16 in Figure 1, which are incident on the diffraction grating at the effective angle of incidence $\beta < |45°|$ and which are of wavelengths in the region of 550 nm.

If the diffraction grating is turned through 90° about the normal 15, so that the preferred direction k is oriented perpendicularly to the plane of the drawing in Figure 2, the p-polarised light is absorbed and s-polarised light diffracted by the diffraction grating, always with respect to the diffraction plane.

The advantage of the polarisation capability of the retroreflector according to the invention is that, on the basis of polarisation of the light beams 14 backscattered by the retroreflector, the orientation of the retroreflector or the preferred direction k of the microstructure 17 can be established from a great distance.

Reference is now directed to Figure 3 showing a matt structure 18 which can be used as a microstructure as indicated 17 in Figure 2. Microscopically fine relief structures are randomly distributed in the matt structure 18, and for that reason the matt structure 18 can only be described by statistical characteristic parameters such as for example mean roughness value R_a, correlation length l_c and so forth. The microscopically fine relief structure elements of the matt structure 18 determine the scatter capability. The parameter consisting of the mean roughness value R_a is in the range of between 20 nm and 5000 nm, with preferred values of between 50 nm and 1000 nm, and corresponds to the optically effective fine structure depth t of the diffraction grating. The greatest differences in height as indicated by H within the matt structure 18 amount to a multiple of the mean roughness value R_a. The parameter of the correlation length l_c, at least in one direction, is of values in the range of between 200 nm and 50,000 nm, preferably between 500 nm and 10,000 nm. If the microscopically fine relief structure elements do not have any azimuthal preferred direction, that arrangement then involves what is referred to as an isotropic matt structure 18. The light 13 which is incident on the isotropic matt structure 18 is reflected in a spatial angle which is predetermined by the scatter capability of the matt structure 18 and which is centered around the axis of the incident light 13. The level of intensity of the scattered light uniformly decreases in all directions from the axis of the spatial angle. The spread of that angle is determined by an intensity limit value which is predetermined by visual or machine readability. Severely scattering matt structures 18 distribute the scattered light in a larger spatial angle than a weakly scattering matt structure 18. If the microscopically fine relief structure elements are on average azimuthally oriented on to a preferred direction k, the matt structure 18 provides for anisotropic scattering of the incident light, in which respect the predetermined spatial angle of the matt structure 18 is of a cross-sectional configuration in the form of an ellipse, the larger or main axis of which is perpendicular to the preferred direction k of the relief structure elements.

In contrast to the diffractive structures the matt structures 18 scatter the incident light 13 practically independently of the wavelength thereof.

The design configuration of the retroreflector in which the microstructure 17 superimposed on the relief structure 18 is one of the matt structures 18 advantageously involves an increased divergence, which is determined by the scatter capability, in respect of the light beams as indicated at 14 in Figure 2, which are backscattered from the retroreflector. In addition, the level of light intensity in the spatial angle of the backscattered light beams 14 is averaged out and any diffraction effects occurring are suppressed. Those properties are particularly advantageous if the incident light indicated at 13 in Figure 2 is of one color or if the retroreflector is used for road markings or traffic signs.

Attention is now directed to Figure 4 showing a retroreflector according to the invention disposed on the front side of a traffic or road sign. For superimposition in respect of the relief structure indicated at 8 for example in Figure 1, the retroreflector advantageously has surface portions or elements 27, 28 with anisotropic matt structures as indicated at 18 in Figure 3 as the microstructure indicated at 17 in Figure 2. The preferred direction k thereof is oriented vertically in the image pattern 20, for example of a traffic signal 19, a corporation plaque or the like, the pattern 20 being formed by the surface elements 27, 28.

The material of the structure layer referenced 3 in Figure 1 and/or the base foil referenced 7 in Figure 1 acts as a color filter and is transparent. The color filter of the surface elements 27, 28 is selected according to the colors for the image pattern 20 of the traffic sign 19. The incident light 13 produced by a light source indicated at 21 in Figure 4, for example a vehicle headlamp, is reflected by the retroreflector in the spatial angle which is predetermined by the matt structure 18. The intensity of the reflected light beams 14 is concentrated in a horizontal ellipse 23 which, in a notional plane 22 disposed at the location of the light source and in perpendicular relationship to the reflected light beams 14, shows the cross-section of the spatial angle of the reflected light beams 14. For road users,

such traffic signs 19 afford optimum visibility in the dark, in the light 13 of their light sources 21.

In another possible embodiment of the layer composite indicated at 2 in Figure 1 the microstructure 17 superimposed on the relief structure 8 is a superimposition comprising a periodic diffraction grating and one of the matt structures 18. That configuration of the retroreflector affords the advantage that it combines both the polarisation capability of the diffraction grating and also the advantages of the above-described matt structures. The scatter capability of the matt structure 18 influences polarisation of the backscattered light beams 14 not at all or only very slightly.

Referring now to Figure 5a, shown therein is a portion of the layer composite 2 with a simple configuration of the relief structure 8, in the form of a linear grating. The grating here involves a symmetrical sawtooth profile, the grooves of which are of a V-shaped configuration, with the mutually perpendicularly arranged side walls 10. The microstructure indicated at 17 in Figure 2 is too fine to be visible in Figure 5a. Figure 5b shows a plan view of the relief structure 8. The side faces 10 which are marked by a dot pattern are the side faces which are not shown in Figure 5a. The structure elements referenced 9 in Figure 1 are prisms with an isosceles, right-angled triangle as the end cover face 24. The prisms lie with their hypotenuse face on the notional base plane 12 which is oriented in parallel relationship with the surface 11 of the layer composite 2.

Reference is now made to Figure 6a showing another possible embodiment of the relief structure 8 in the layer composite 2. Once again the microstructure shown at 17 in Figure 2 is not illustrated here. The relief structure 8 is a superimposition of at last two linear gratings forming a cross grating arrangement. The linear gratings have the above-described symmetrical sawtooth profile. The structure elements indicated at 9 in Figure 1 which are arranged on the base plane indicated at 12 in Figure 5a are in the form of pyramids 25. If only two linear gratings cross at a right angle, the pyramids 25 have a square base surface in the base plane 12, as is shown in Figure 6b as a plan view on to the relief structure 8. In Figure 6b, the four side faces 10 of each pyramid as indicated at 25 in Figure 6a

are distinguished from each other by means of dot patterns of differing densities. The angle of inclination ϑ as shown in Figure 1 in respect of the side faces 10 with respect to the base plane 12 is 45°.

Looking now at Figure 7, shown therein is a structure element 9 of another embodiment of the relief structure indicated at 8 in for example Figure 6b. The relief structure 8 is produced by the section of three linear gratings involving a symmetrical sawtooth profile. In this case the structure elements 9 are in the shape of a tetrahedron, the base surface of which is in the base plane 12. In the preferred configuration the grooves of the three gratings intersect at an angle of 60° so that the base surface of the tetrahedron forms an equilateral triangle. The angle of inclination ϑ as shown in Figure 1 in respect of the side faces 10 with respect to the base plane 12 is 45°.

Further structure elements 9 are suitable for the relief structure 8, for example pyramids as indicated at 20 in Figure 5a, the base surface of which is defined by a regular polygon.

It will be noted that the tips of the structure elements 9 which are illustrated in Figures 5 through 7 all face towards the surface indicated at 11 for example in Figure 5a. The same effect is achieved by a negative configuration of the structure elements 9, in which case the tips thereof are on the base plane 12. As viewed from the surface 11 therefore, the structure elements 9 are then of a funnel-like configuration.

Reference will now be made to Figure 8 showing a special case in which the structure element 9 is in the form of a right circular cone with an opening angle of 90°, which is disposed standing with its tip on the base plane 12 in a perpendicular position. The side faces indicated at 10 in Figure 7 of the structure element 9 are so-to-speak degenerated to form peripheral lines indicated at 26. In the case of a cone which is suitable for the retroreflector according to the invention, all lines 26 include an angle of inclination $\vartheta = 45°$ with respect to the base plane 12.

Figure 9 shows a possible configuration of a retroreflector in accordance with the invention in the form of a machine-readable, optically encoded marking which advantageously utilises polarisation of the

microstructure indicated at 17 in Figure 2. The retroreflector is divided into mutually juxtaposed surface portions or elements 27, 28. The microstructures 17, which are respectively superimposed on the relief structure indicated at 8 in Figure 1, of the adjacent surface elements 27, 28 act as polarisers and differ only in respect of their preferred direction k_1 and k_2 respectively. Identification of the surface element 27, 28 which is irradiated with incident light as indicated at 13 is effected solely on the basis of the direction of polarisation of the reflected light beams 14. The reflected light beams 14 return to the light source 21 in almost parallel relationship with the incident light 13 and are received by a detector arrangement diagrammatically indicated at 29 arranged directly beside the light source 21. The detector arrangement 19 is designed to determine the direction of polarisation of the light beams 14, for example with polarisation filters arranged in front of the detector elements, as analysers.

The light source 21, with the incident light 13, produces a light spot 30 on the surface elements 27, 28. A deflection device 31, for example a rotating or tilting mirror, deflects the beam of the incident light 13 which, with the light spot 30, successively scans the surface elements 27, 28. As the reflected light beams 14 are oriented almost parallel to the incident light 13, the deflection device 31 projects the returning light beams 14 to the detector device 29.

The admissible reading distance will depend on the parallelism of the light 13 incident from the light source 21 in the beam, the light spot 30 of that light being of a dimension which corresponds at most to the smallest dimension of the surface elements 27, 28. The detector arrangement 29 is operable to detect at least at one moment the reflected light beams 14 when the light spot 30 is completely within one of the surface elements 27, 28.

The optically encoded marking of the retroreflector with the polarising microstructures 17 affords the advantage that the optical marking is machine-readable over a distance of some meters, typically up to around 10 meters, by a compact assembly 32 which comprises the light source 21, the detector arrangement 29 and the mirror of the deflection

device 31, and polarisation of the reflected light beams 14 is recognised, against the background of the surroundings. In comparison therewith the known optically encoded markings can only be read from distances of at most some centimeters.

In an alternative configuration the machine-readable, optically encoded marking can be in the form of a bar code and can be disposed in the layer composite 2. The bar code has for example mutually parallel rectangular surface portions or elements 27, 28 as the bar elements, which are arranged at mutual spacings in a background field as indicated at 33 in Figure 9. An item of information is encoded in bar elements of varying widths and in the spacing of the adjacent surface elements 27, 28. The relief structures 8, which are superimposed with the microstructure 17, of the surface elements 27, 28 and of the background field 33 differ in respect of the preferred directions k_1, k_2 of the microstructure 17, in which respect the preferred direction k_1 for the surface elements 27, 28 and the preferred direction k_2 in respect of the background field 33 include an azimuth angle in the range of between 30° and 90°. That bar code is machine-readable over a great distance, in particular with parallel coherent laser light.

The microstructure 17 which is superimposed on the relief structure 8 and which in turn is the periodic diffraction grating superimposed with one of the matt structures indicated at 18 in Figure 3 is advantageously employed for use of the machine-readable, optically encoded marking. The matt structure 18 suppresses the diffraction effects at the relief structure 8 and determines the spatial angle of the reflected light beams 14 and the cross-section thereof.

It will be noted at this juncture that the surface elements 27, 28, the background field 33 and a field indicated at 34 with retroreflectors oriented in a predetermined fashion are also suitable for making up security patterns for optically variable security elements which are composed in a mosaic-like manner from surface portions 35, 36 occupied by diffractive gratings and which are in use on banknotes and other documents of all kinds. Diffractive security elements of that kind are described for example in EP-A 0 105 099, EP-A 0 375 833 and others, to which reference is hereby directed for

incorporation thereof. The structures of the diffractive gratings, which are covered by the reflection layer indicated at 6 in Figure 1, are formed in adjacent relationship with regions with the retroreflectors, in the parallel base plane indicated at 12 in Figure 1, and enclosed between the layers indicated at 3 and 4 in Figure 1 of the layer composite 2. The surface portions 35, 36 differ from the respectively adjacent surface regions in respect of at least one of their grating parameters such as spatial frequency, grating vector, grating profile and so forth. From the point of view of an observer (not shown), the surface elements 27, 28 occupied by retroreflectors, the background field 33 and the field 34 are only visible as a light surface when light is incident on the security element in approximately parallel relationship with the direction of view of the observer, while the surface portions 35, 36 with the diffractive gratings are dark. Conversely, under opposite lighting conditions, the surface portions 27, 28, 33, 34 with the retroreflectors remain dark while the surface portions 35, 36 are light, corresponding to the orientation of their grating vectors and their spatial frequency, when the security element is rotated in its own plane.

In an embodiment of the security pattern for example the surface portions 35, 36 are arranged on the field 34 serving as a background while in another embodiment the above-described optically encoded marking with the surface elements 27, 28 and optionally with the background field 33 is integrated into the security element, in which case the line-shaped surface portions 35 of a width of at most 0.2 mm may also extend over the surface elements 27, 28 and the background field 33. That combination has the advantage that the optically encoded marking is optimally adapted to machine reading, but it is visually not perceptible to an observer.

In a further configuration of the optical marking the background field 33, instead of the retroreflector, may also have a diffractive grating of the security element.

It will be appreciated that the above-described embodiments and configurations of the invention have been set forth solely by way of example and illustration of the principles thereof and that various other

modifications and alterations may be made therein without thereby departing from the spirit and scope of the invention.